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Small hydropower (SHP) development in Nigeria: An assessment

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ABSTRACT

This paper evaluates small hydropower (SHP) development and examines the current situation in Nigeria with respect to the established policies and Energy Power Sector Reform (EPSR) Act 2005. Hydropower sector witnessed about 360% growth between 1971 and 2005 and yet only about 5% of the vast small hydropower (SHP) potential is tapped by the few plants built between 1923 and 1964. Operating and maintenance costs are in favor of SHP development in the country, being the lowest when compared with the situation in European countries. The Nigerian Government has taken steps to diversify energy sources in order to promote renewable energy development by encouraging private investments in the energy sector through reforms, but this may not be adequate as there remain barriers against SHP development in the country. It is concluded that government must incorporate subsidies, feed-in-tariffs, and framework for Price Purchase Agreements (PPA) into the policies in order to further promote renewable energy and attract both indigenous and foreign investments for quick adoption and rapid expansion of SHP technologies.

Contents

1. Introduction

Energy is a very important ingredient for development and a powerful engine of social and economic opportunity in that no country can manage to develop beyond a subsistence economy without having at least minimum access to energy services for the larger proportion of its population [1]. Studies have indicated a strong correlation between energy consumption and economic growth; access to modern energy services directly contribute to economic growth and poverty reduction via the creation of wealth. China for example has moved 300 millions of her people out of poverty since 1990 through increased access to energy [2]. One major driver of energy demand is population, its rapid increase coupled with industrialization in the 20th century brought about a huge energy demand [3,4]. According to Kucukali and Baris [4], the total world consumption of marketed energy is projected to increase by 57% for the period from 2004 to 2030; this means that much of the world's energy is currently produced and consumed in such a way that the level of consumption cannot be sustained, if technology remains constant and overall quantities of energy do not increase substantially.

In Nigeria, the economy became private-sector-driven from the inception of the democratic dispensation in 1999. This paved the way for the approval of a number of policy frameworks to improve energy supply infrastructure in order to cope with the fast growing population. Among these frameworks are the National Energy Policy (NEP), the passage of the Electric Power Sector Reform Act (EPSR) and the establishment of the Nigerian Electricity Regulatory Commission (NERC). Through these, complete government control of power generation and distribution was removed while the activities of all stakeholders and issuance of operating licenses to various parties in the power sector were better managed.

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Table 1
Installed generation capacity and electricity production between 1999 and 2005.

Year	Generation installed capacity (MW)			Energy produced (GWh)		
	Thermal	Hydro	Total	Thermal	Hydro	Total
1999	3680	1900	5580	8700.73	7298.51	15999.24
2000	3680	1900	5580	8217.78	6441.6	14659.38
2001	4245	1900	6145	10760.68	6193.53	16954.21
2002	4280	1900	6180	13210.01	6390.49	19600.5
2003	4280	1900	6180	15015.46	7752.67	22768.13
2004	4230	1900	6130	16122.04	8086.88	24208.92
2005	4230	1900	6130	14542.49	6093.25	20635.74

Source: National Bureau of Statistics [15].

Nigeria is endowed with abundant natural energy carrier resources including crude oil, natural gas, coal and lignite, tar sand, hydropower (large and small), solar radiation, wind, biomass (fuelwood, animal and plant wastes) and nuclear element deposits. Some of these resources are yet to be exploited while the maximum utilization of others is not in view, thus making energy a major concern and priority in the country. Hence, rapid growth in the energy demand above production levels has therefore always been the result of resources underutilization.

Hydropower was the type in use in Nigeria before the discovery of crude oil. However, there was a shift in attention to fossil fuels due to the vast deposits in the country leading to the decay of the hydropower sector. The result was that the existing hydro plants (Kainji, Jebba and Shiroro) were neglected to the extent that they performed well below installed capacity. And yet no interest was shown in building new hydro plants (Table 1), until recently when the energy situation showed clearly that conventional energy sources had failed the nation in spite of all the fossil based Independent Power Projects licensed as at February 2009 (Table 2).

The contribution of natural gas needed by these thermal plants has continually been cut down by flaring as most of the oil fields lack appropriate infrastructure for gas production. Oil production has also suffered from bunkering, sabotage and insecurity in the Niger Delta that seriously shut-in crude production and stalled major oil and gas projects. Hydropower has received a renewed interest in recent years although its share in total electricity production shows a decreasing trend when compared with thermal plants (Fig. 1).

However, until the proposed 2600 MW Mambilla large hydropower is completed together with the adoption of small hydropower (SHP) plants and technologies, the decreasing trend (Fig. 1) is expected to continue as water inflow into the Kainji lake which feeds Kainji and Jebba power plants will soon witness a drastic reduction and especially if the dam proposed by Niger Republic on the Niger River is constructed.

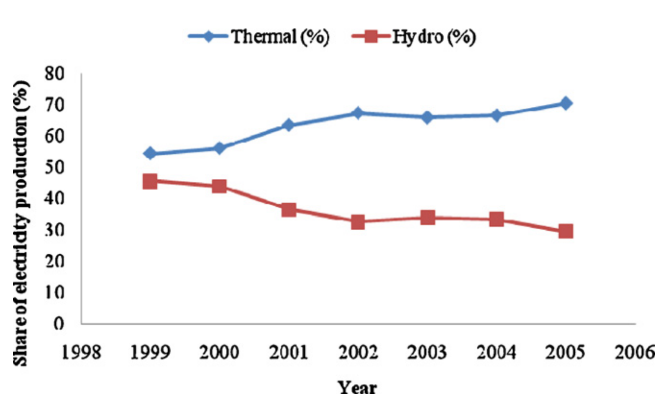

Fig. 1. Thermal and hydropower contribution to total electricity production in Nigeria between 1999 and 2005.
Source: National Bureau of Statistics [15].

For many centuries, water is a resource that has been exploited for various purposes. Hydropower is the leading source of renewable energy, providing more than 97% of all electricity generated by renewable sources and approximately 22% of the world's electricity production, most of which is SHP <10 MW [4,5]. Small hydropower represents the highest density resource and stands in first place in the generation of electricity from renewable sources throughout the world among all the non-conventional renewable energy sources [6]. It has no internationally agreed definition and its classification is based only on a country's level of hydropower development as shown in Table 3.

The global installed capacity of SHP is around 47,000 MW against an estimated potential of 180,000 MW. China on the one hand has over half of the world's developed small hydro capacity in about 42,000 stations with an installed capacity of over 35,000 MW. According to Kucukali and Baris [4], about 19,000 micro- and 19,606 mini-hydropower plants with total installed capacities of 687 and 7171 MW respectively were constructed between 1994 and 2004. Nigeria on the other hand has large SHP potentials considering her numerous rivers and dams which can be economically tapped for many applications in remote, off-grid communities and grid based power generations (Fig. 2).

2. Small hydropower in Nigeria

Nigeria ranked ninth in hydropower potential in Africa with technical hydropower energy at 32,450 GWh/yr as revealed in Table 4. She used 21.5% (6986 GWh/yr) of her potential for the year 2001; the situation in other African countries with respect to the exploitation of their respective hydropower potentials was similar.

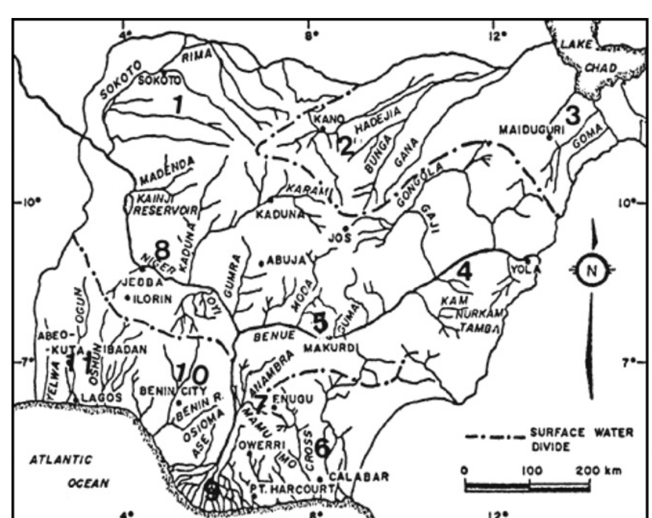

Fig. 2. Map of Nigeria showing major rivers and hydrological basins.
Source: FAO available at http://www.fao.org/docrep/008/ad793b/AD793B01.htm.

Table 2
Licensed independent power producers (IPP) as at February 2009.

S/N	Name of applicant	Type of license	Date of grant of licence	Total capacity (MW)	Fuel type	Site location	State	Phases		
								Phase 1 (MW)	Phase 2 (MW)	Phase 3 (MW)
1	Ethiope Energy Ltd.	1	24/08/2006	2800	Gas	Ogorode, Sapele	Delta	1390	1410	–
2	Farm Electric Supply Ltd.	1	24/08/2006	150	Gas	Ota	Ogun	150	–	–
3	ICS Power	1	25/08/2006	624	Gas	Alaoji	Abia	120	504	–
4	Supertek Nigeria Ltd.	1	24/08/2007	1000	Gas	Akwete	Abia	480	204	316
5	Mabon Ltd.	1	07/12/2006	39	Hydro	Dadinkowa	Gombe	39	–	–
6	Geometric Power Ltd.	1	07/12/2006	140	Gas	Aba	Abia	140	–	–
7	Aba Power Ltd.	2	07/12/2006	–	–	Aba	Abia	–	–	–
8	Westcom Technologies & Energy Services Ltd.	1	23/02/2007	1000	Gas	Sagamu	Ogun	500	500	–
9	Lotus & Bresson Nigeria Ltd.	1	12/04/2007	60	Gas	Magboro	Ogun	60	–	–
10	Anita Energy Ltd.	1	12/04/2007	90	Gas	Agbara	Lagos	90	–	–
11	First Independent Power Ltd.	1	11/05/2007	150	Gas	Omoku	Rivers	150	–	–
12	First Independent Power Ltd.	1	11/05/2007	136	Gas	Trans Amadi	Rivers	136	–	–
13	First Independent Power Ltd.	1	23/05/2007	95	Gas	Eleme	Rivers	95	–	–
14	Hudson Power Station Ltd.	1	23/05/2007	150	Gas	Warewa	Ogun	150	–	–
15	Ibafo Power Station Ltd.	1	23/05/2007	200	Gas	Ibafo	Ogun	200	–	–
16	Shell Distribution Co Ltd.	1	23/05/2007	640	Gas	Afam	Rivers	640	–	–
17	Agbara Shoreline Power Company Ltd.	1	28/09/2007	100	Gas	Agbara	Ogun	100	–	–
18	Nigerian Agip Oil Company Ltd.	1	29/11/2007	480	Gas	Okpai	Delta	480	–	–
19	Ikorodu Industrial Power Ltd.	1	14/01/2008	140	Gas	Ikorodu	Lagos	140	–	–
20	Minaj Holdings Ltd.	1	14/02/2008	115	Coal	Enugu	Enugu	100	15	–
21	Ibom Power	1	12/05/2008	190	Gas	Ikot Abasi	Akwa Ibom	190	–	–
22	Notore Power	1	22/09/2008	50	Gas	Onne	Rivers	50	–	–
	Sub-total on grid			*8349*				*5400*	*2633*	*316*
23	Ewekoro Power Ltd.	3	07/12/2006	13	Gas	Ewekoro	Ogun	13	–	–
24	Ikorodu Industrial Power Ltd.	2	08/12/2006	–	–	Ikorodu	Lagos	–	–	–
25	Ikorodu Industrial Power Ltd.	4	23/02/2007	39	Gas	Ikorodu	Lagos	9	30	–
26	CET Power Project Ltd.	3	28/09/2007	20	Gas	Tinapa	Cross River	20	–	–
27	CET Power Project Ltd.	3	22/12/2008	5	Gas	Nigerian Breweries Ltd Iganmu	Lagos	5	–	–
28	Tower Power Utility Ltd.	3	22/12/2008	20	Gas	Ota	Ogun	20	–	–
	Sub-total			*97*				*67*	*30*	–
	Grand total			*8446*				*5467*	*2663*	*316*

1, generation on grid; 2, distribution; 3, generation off-grid; 4, embedded.
Source: Sambo AS. The challenges of sustainable energy development in Nigeria. Nigerian Society of Engineers Forum, Abuja; 2009.

Table 3
SHP definition and classification in some selected countries and organizations.

Country/organization	Micro (kW)	Mini (kW)	Small (kW)
IN-SHP	<100	101–500	501–10,000
UNIDO	<100	101–2000	2001–10,000
ESHA	–	–	<15,000
China	<100	101–500	501–25,000
Philippines	–	51–500	<15,000
Sweden	–	–	101–15,000
USA	<500	501–2000	<15,000
India	<100	<2000	–
Japan	–	–	<10,000
Nigeria	≤500	501–1000	1001–10,000
France	<500	501–2000	–
New Zealand	–	<10,000	<50,000
United Kingdom	<1000	–	–
Zimbabwe	5–500	501–5000	–
Canada	–	<1000	1001–1500

Source: Jiandong T. Small hydro power – China's practice. China Water Power Press; 2005.

According to ECN [7], Nigeria has a gross exploitable large hydro potential of 14,750 MW out of which 14% amounting to 1930 MW is harnessed, contributing approximately 30% of total installed grid connected electricity generation.

SHP has been in existence in Nigeria since 1923, 45 years before the commissioning of the country's first large hydropower (Kainji). Today, SHP technology is still at its infancy with the schemes operated in only three States of the Federation [7] as shown in Table 5.

Unlike in developed countries where SHP plants find broad adoption in electricity production and other applications, little attention is given to its significance in spite of the vast potential and the high energy need in Nigeria. Table 6 reveals the installed capacities of SHP plants in EU and the world between 1980 and 2010 [4].

It was also established through a 1980 survey of some States that an SHP potentials of 734 MW is available in 277 sites (Table 7); however, a 2004 estimation indicated a total SHP capacity of 3500 MW representing 23% of the nation's hydropower potential if the remaining States were surveyed [7].

Furthermore, the projected power demand for SHP as shown in Fig. 3 revealed that the country needed 190, 490, 1280 and 3315 MW for 2000, 2010, 2020 and 2030 respectively and yet only 30 MW capacity is being harnessed, representing approximately 16% of the 2000 demand indicating a wide disparity and deficiency in supply relative to demand. In view of this, SHP potential is underexploited in Nigeria even though the potential exists to meet the projected 2030 demand, if other sites are fully harnessed.

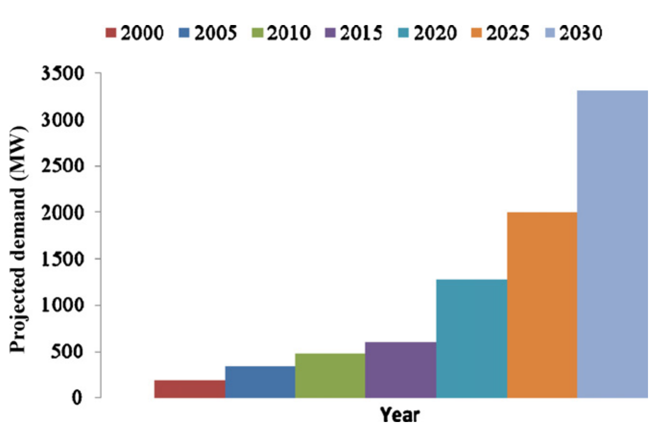

Fig. 3. Projected demand of SHP in MW.
Source: Renewable Electricity Action Plan [13].

Table 4
Hydropower situation of selected countries in Africa.

Country	Gross theoretical hydropower potential (GWh/yr)	Technically feasible hydropower potential (GWh/yr)	Economically feasible hydropower potential (GWh/yr)	Installed hydro capacity (MW)	Production from hydro plants (GWh/yr)	Percentage of electricity produced from hydro	Hydro capacity under construction (MW)	Planned hydro capacity (MW)
Algeria	12,000			280	500	2		700 (p-s)
Angola	150,000	90,000	65,000	290	1000	56	780	<16,500
Cameroon	294,000	115,000	103,000	725	2423	99		600
Congo		>50,000		89	352	>90		180
Congo DR	1,397,000	774,000	<419,210	2400	5350	99	4	43,000
Cote d'Ivoire	46,000	>12,400	12,400	614	1800	60		334
Egypt		>50,000	50,000	2810	11,450	20	65	193
Ethiopia	650,000		260,000	398	1600	97	297	705
Ghana		10,600		1072	5169	71		400
Madagascar	321,000	180,000	49,000	105	510	72	42	350
Morocco		4700	4000	1205	2350	18	90	450 (p-s)
Mozambique	50,000	37,647	31,717	2180	11,548	94		2000
Nigeria	42,750	32,450	29,800	1938	6986	43	64	4850
South Africa		n/a		668	904	0		n/a
Tanzania	39,447	20,000	1789	377	1748	85	180	>1000
Zambia	52,460	28,753	11,000	1674	7782	100	60	>2000
Zimbabwe	18,500	17,500		670	3000	25	85	>800

n/a, data not available (but greater than zero); p-s, pump storage.
Source: World atlas on hydropower and dams [16].

Table 5
Small hydro scheme in existence in Nigeria.

River	State	Installed capacity (MW)
Bagel I	Plateau	1
Bagel II	Plateau	2
Ouree	Plateau	2
Kurra	Plateau	8
Lere	Plateau	4
Lere	Plateau	4
Bakalori	Sokoto	3
Tiga	Kano	6
Total		30

Source: Renewable Energy Master Plan (REMP) [7].

In 1976, Nigeria was divided into 11 river basins (see Fig. 2) through the establishment of River Basins Development Authorities for the purpose of irrigation, water supply, navigation, hydroelectric power generations, fisheries and recreational facilities, and accomplished through the construction of small, medium and large dams to impound surface waters. Nigeria has a good topography which ranges from lowlands along the coast and in the lower Niger valley to high plateaus and mountains in the north as well as along the eastern border with elevation ranging from 600 m to a 2042 m. Most of the rivers and dams are favored with good elevation for various SHP utilizations. The large hydro power plants comprising Kainji (760 MW), Jebba (570 MW) and Shiroro (600 MW) were constructed on the Kainji and Shiroro Rivers while Mambila, a proposed project on the Benue River, has a capacity above 2600 MW. All of these rivers and dams have several adequate heads for SHP development.

3. Government policy towards SHP

Electricity generation from renewable energy sources has received tremendous support in developed countries leading to their full contribution to the total energy mix. This is reflected in the increasing trend in power output of SHP as shown in Table 5. In Kucukali and Baris [4], the main instruments for promoting renewable energy in developed countries are fed-in tariffs, quota obligations, tenders and energy tax exemptions.

Natural gas supply to Nigeria's thermal power stations has been grossly inadequate; it is less than one-third of the needed 1.2 billion standard cubic feet of gas per day. However, to increase the energy production, there is need for enhancement of the existing sources and full exploitation and promotion of the country's huge renewable energy sources. Going by the vast SHP potential at present and satisfactory performance of the existing small hydro stations in the country, energy generation through SHP will be regarded as one of the most stable and economically clean renewable energy options in Nigeria.

Due to the reform of the Nigerian electricity industry after the inception of the democratic dispensation in 1999, several laws and regulations were enacted to exploit and promote the nation's abundant renewable energy deposits, for a full contribution to the total energy mix. The reform commenced with the preparation of a National Electric Power Policy (NEPP) in 2001 followed by the preparation and passage of the enabling legislation, referred to as the Electric Power Sector Reform Act (EPSR) into law in March 2005 [8]. The Act was to replace the repealed Decree No 24 of 1972 which established the National Electric Power Authority (NEPA). According to Dayo [8], the NEPP envisaged a three-stage legal and regulatory reform comprising: (i) a transition stage characterized by private power generation via Independent Power Producers (IPPs) and Emergency Power Producers (EPPs), corporate restructuring, unbundling and privatization of NEPA, (ii) a medium-term stage characterized by energy trading between generation and distribution companies on the basis of bilateral contracts and (iii) a long-term competition structure characterized by the optimal operation of the various power generation, transmission and distribution companies. The EPSR Act provides for the vertical and horizontal unbundling of the electricity company into separate and competitive entities, the development of a competitive electricity markets, setting out of a legal and regulatory framework for the sector, a framework for rural electrification, framework for the enforcement of consumer rights and obligations and establishment of performance standards. Table 8 shows the objectives of the legal, regulatory and institutional framework for the power sector in Nigeria. With the passage of the EPSR Act, NEPA was deregistered and the Power Holding Company of Nigeria (PHCN) was incorporated to manage the unbundling of NEPA.

Table 7
Small hydro potential in surveyed states of Nigeria.

State (Pre 1980)	River basin	Total sites	Total capacity (MW)
Sokoto	Sokoto-Rima	22	30.6
Katsina	Sokoto-Rima	11	8.0
Niger	Niger	30	117.6
Kaduna	Niger	19	59.2
Kwara	Niger	12	38.8
Kano	Hadeija-Jamaare	28	46.2
Borno	Chad	28	20.8
Bauchi	Upper Benue	20	42.6
Gongola	Upper Benue	38	162.7
Plateau	Lower Benue	32	110.4
Benue	Lower Benue	19	69.2
Rivers	Cross River	18	258.1
Total		277	734.2

Source: Renewable Energy Master Plan (REMP) (2005).

The reform broke the monopolistic framework in the power sector thereby allowing: (i) private operators to apply for and obtain a license through the Nigerian Electricity Regulatory Commission (NERC) to build and operate a power plant with aggregate capacity above 1 MW and (ii) the establishment of the Rural Electrification Agency (REA) together with an independent Rural Electrification Fund (REF) whose major objective is to fully incorporate renewable energy in the energy options. According to the NERC [9], the EPSR Act however allows a person to construct, own or operate an off-grid power plant not exceeding 1 MW in aggregate at a site without a license. This exemption to holding a license favors energy generation through SHP since most water potentials for SHP fall within the required range and is expected to draw private participation to mini- and micro-hydropower investment especially for rural development and off-grid generation. Since inception, the NERC has issued a total of 29 licenses (see Table 2), including 20 for grid-connection, two each for embedded and distribution and five others for off-grid generation; five of the latter are already in operation, with four others ready for commissioning. Six out of the

Table 6
Growth in SHP capacity in European Union and the world.

	1980	1985	1990	1995	2000	2005	2010
EU installed capacity (MW)	5900	6700	7700	9000	9600	10,300	11,000
World installed capacity (MW)	19,000	21,000	24,000	27,900	37,000	46,000	55,000

Source: Kucukali and Baris [4].

Table 8
Legal, regulatory and institutional framework for the power sector in Nigeria.

Policy	Enactment date	Objectives
NEPP	March 2001	Promotion of total liberalization and competition in the power industry Promotion of private sector participation
EPSR Act	March 2005	The bill seeks to: Provide for the formation of companies to take over the functions, assets, liabilities and staffs of NEPA Develop competitive electricity market and establishment of NERC, REA and REF Provide for the licensing and regulation of the generation, transmission, distribution and supply of electricity Enforce performance standards, consumer rights and obligations and determination of tariffs
NERC	October 2005	To carry out economic and technical regulations in the power sector Issuance of licenses to market participants Ensuring compliance with market rules and other operating guidelines
NEP	April 2003	To increase the percentage contribution of hydro electricity to the total energy mix To extend electricity to rural and remote areas, through the use of mini and micro hydro power schemes To conserve non-renewable resources used in the generation of electricity To diversify the energy resources base To ensure minimum damage to the ecosystem arising from hydropower development To attract private sector investments into the hydropower sub-sector To ensure minimum damage to the ecosystem arising from hydropower
REA	April 2006	Extending the national grid Facilitating independent off-grid systems Generating renewable energy power Coordinating renewable electricity activities among state and federal agencies. Managing REF
REF	October 2006	Managing the Renewable Electricity Trust Fund to finance renewable electricity projects

Source: National Energy Policy (NEP) [17], Dayo [8].

eight off-grid generators are also in operation, with the remaining two are expected to start up soon.

In spite of the frameworks put in place to encourage renewable energy investments as in Table 8, private sector participation has increased only in fossil-based sources rather than in hydropower and other renewable sources as shown in Table 2. There is still little awareness of the benefits and opportunities of SHP as a power generation source if we compare the quantity exploited with the existing potentials, while at the same time a current and extensive hydrological database is not in existence for prospective investors. So far, private sector participation in renewable energy implementation in the country is in the area of importation and marketing of components. With full private sector involvement in hydro generation, especially in the form of investment towards the maximum utilization of SHP potential as encouraged by NEPP and NEP, Nigeria's economically feasible hydropower potential is expected to exceed 29,800 GWh/yr, calculated before the enactment of NEPP.

4. SHP a sustainable energy technology

As suggested earlier, a secure supply of energy is generally agreed to be necessary, but not sufficient requirement for development within a society. Sustainable development within a society requires a supply of energy resources that, in the long term, is readily and sustainably available at reasonable cost and can be utilized for all required tasks without causing negative societal impacts [10]. According to Dudhani et al. [6], SHP projects are generally considered to be more environmentally favorable than both large hydro and fossil fuel powered plants because they do not involve serious deforestation, rehabilitation and submergence.

Small-scale hydropower is economically competitive with small-scale fossil fuel/steam-electrical plants particularly if the hydro sites are located near electricity demand centers and are truly sustainable in the sense of being able to fully account for their environmental and social costs. The net cost savings resulting from the use of local materials and labor, standardized power plants, ease of local development of the technology make it a preference for remote applications, off-grid and to rural dwellers in the proximity of their habitat. SHP is environmentally friendly because the relevant technologies do not need the construction of large dams, mitigation of mass population, or involve the deforestation and silting problems usually associated with large hydropower [6]. According to the World Bank [11], it is observed that a 2.5 MW hydro scheme produces the same amount of electricity as a 2.5 MW baseline power plant provided through gas-based power plants. In Nigeria, the emission factor for gas-based heat and electricity generation is 670 g CO_2/kWh. Hence, an assumed operating time of 7000 h/yr of hydro plant will result in annual savings of about 11,500 tons CO_2 emissions/yr while an anticipated lifetime of 25 years will result in savings of approximately 290,000 tons CO_2 emissions using the hydro plant. It is clear from the above facts that the adoption and development of SHP in Nigeria will be a renewable source for sustainable development.

5. Financing SHP in Nigeria

Studies have shown that one of the main obstacles to implementing renewable energy projects in Africa is not the technical feasibility of the projects, but the absence of low-cost, long-term financing. This is further complicated by competition for limited funds by the diverse projects which become critical, if the country is operating under unfavourable macro-economic conditions [12].

Through the reform programme, competition in the power industry was promoted in a bid to meet the growing electricity demand. However, since fossil fuels have not been able to resolve the persistent energy challenge of the country, despite the abundance, the need for electricity generation through renewable energy sources has been constantly expressed. This explains why Nigeria plans to add a cumulative 735 MW renewable electricity generating capacity (see Table 9) within a 10-yr targets 2007–2016 to the grid, together with the following energy contributions to the economy: (i) 5% contribution to total electricity generation, excluding large hydropower, (ii) 5 TWh of energy, (iii) 2 million new connections to the grid, (iv) 1 million solar home systems, (v) 2000 rural school electrification, (vi) 2000 rural solar clinic electrification, (vii) 10,000 solar street lights, (viii) 100 billion Naira renewable electricity industry and (ix) 1.2 MT CO_2 emission reduction [13].

Table 9
Renewable energy targets for Nigeria electricity sector based on peak demand.

Renewable type	2007 (MW)	2010 (MW)	2016 (MW)
Small hydro	50	100	400
Solar PV	10	20	130
Wind	0	20	100
Bagasse cogeneration	0	15	105
Total renewable (MW)	60	155	735
% total	1	2	5

Source: Renewable Electricity Action Plan (REAP) [13].

Table 10
Initial capital costs of electricity generating systems.

Technology	Size (KW)	Initial capital cost ($/KW)
Micro hydro	10–20	1000–2400
Photovoltaic (PV)	0.07	11,200
Photovoltaic (PV)	0.09	8400
Wind turbine	0.25	5500
Wind turbine	4	3900
Wind turbine	10	2800

Source: Renewable Energy Master Plan (REMP) (2005).

A special fund called the Renewable Electricity Trust Fund (RETF) has been established by the Government to accelerate the expansion of renewable electricity in Nigeria. The RETF which shall be managed under the Rural Electricity Fund (REF) according to the 2005 EPSR Act shall be to promote, support and provide renewable electricity through private and public sector participation [13]. As electricity generation via renewable sources is becoming popular in Nigeria, special funding seems inevitable. Nigeria will also benefit from a number of international grants for renewable energy projects. According to the statistics from International Energy Agency [14], the country's hydropower sector shows remarkable growth between 1971 and 2005; the sector generated well below 5000 GWh of electricity in 1971, but the figure rose to approximately 23,000 GWh in 2005. It is for this reason that World Bank will be allocating more than US$ 200 million to aid the development of renewable energy and energy efficiency projects in Nigeria in a bid to enhance the security of supply and provide access to electricity in the country as a whole but particularly in the rural areas.

An examination of the initial capital cost of some renewable energy sources as presented in Table 10, shows that SHP is the cheapest choice of the renewable sources in Nigeria. Table 11 also reveals that the operating and investment cost is much lower in Nigeria than in some of the selected countries in Europe; the low cost further supports SHP investments in Nigeria by individual, indigenous private and foreign organizations.

Table 11
Comparison of the operating and investment costs of SHP in Nigeria with some European countries.

Country	Operating and maintenance cost (€cent/kWh)	Investment cost (€cent/kW)
Belgium	1.8	3700–4960
Germany	5	4000–6000
Greece	2.4–4.2	1000–2000
Spain	3.5–7	1000–1500
France	–	1200–3000
Italy	5–10	1500–3000
Ireland	3.75–9.1	1500–3750
Portugal	–	1300–2500
Finland	3–3.5	2200
UK	5–7	2000–4800
Sweden	4–5	1500–2500
Turkey	1	300–1000
Austria	3.6–14.5	2900–4300
*Nigeria	1.62	–

Source: *Renewable Energy Master Plan (2005) and Kucukali (2009).

6. Conclusion

The effect of Government's reform is clearly positive considering the gradual adoption of renewable energy as an alternative energy source in Nigeria, although relevant policies, legal and institutional frameworks are at a nascent stage. The issuance of licenses by NERC is a clear indication of the desire to diversify sources of electricity and to include renewable energy sources to the energy mix. Furthermore, the enactment of the EPSR Act 2005 can be considered an applause in Nigeria as it allowed legal entities an exemption to license for renewable electricity generation not exceeding 1 MW in aggregate at a site, as well as an exclusion to holding a license for an electricity distribution system with an aggregate capacity not exceeding 100 kW at a site. This is a step needed to provide impetus for the private sector to invest in SHP development.

In spite of the established policies and their performance so far, public and private sector awareness of the opportunities offered by SHP and other renewable energy sources together with the accompanying technologies is still minimal leading to a higher risk perception for intending renewable projects. Government's complete trust in the strength and capacity of fossil fuel energy sources to perform due to the vast deposits in the country has also contributed to the low level of acceptance of SHP and other renewable sources, as reflected in Table 2 in the number of licenses issued that are fossil-based. Subsidies and lower tariffs are also given to encourage importation of conventional energy technologies with none for renewable energy sources are an additional reason for the current situation. The incorporation of feed-in-tariffs and subsidies for renewable energy plants in relevant policies as the case of Germany would further encourage private sector involvement in mini- and micro-hydropower plant installation. A framework for legally binding long-term standardized price purchase agreements (PPA) is also very vital for SHP generation to the grid just as the development of an extensive hydrological database for recent information about potential sites is essential. Such measures will attract both indigenous and foreign investments and further lead to quick acceptance and rapid expansion of the technology.

A major private sector contribution to renewable energy implementation in the country is in the area of the importation and marketing of components; appropriate policies may be formulated to: (i) train manpower for SHP installation, operation and maintenance and (ii) encourage the local manufacture of SHP equipment in domestic markets like the case of China, thereby reducing the high capital costs of renewable energy technologies and equipment, promoting their affordability and thus further encourage hydropower recognition and utilization.

References

[1] Steer A, Stern R, Bond J, Watson R, Georgieva K, Raczynski A. Fuel for thought – an environmental strategy for the energy sector. The World Bank 2000.
[2] Hydropower resource assessment of Africa. In: Ministerial conference on water for agriculture and energy in Africa: the challenges of climate change; 2008. Available at http://www.sirtewaterandenergy.org/docs/2009/Sirte_2008_BAK_3.pdf [accessed 12.07.2010].
[3] Sambo AS, Iloeje OC, Ojosu JO, Olayande JS, Yusuf AO. Nigeria's experience on the application of IAEA's energy model (MAED & WASP) for National Energy Planning. Republic of Korea: Korea Atomic Energy Research Institute; 2006. Available at http://www.energy.gov.ng/index.php?option=com_docman&task=cat_view&gid=21&dir=DESC&order=name&limit=5&limitstart=5 [accessed 04.03.2010].
[4] Kucukali S, Baris K. Assessment of small hydropower (SHP) development in Turkey. Energy Policy 2009;37:3872–9.
[5] Wisconsin valley improvement company. Renewable. Available at http://new.wvic.com/index.php?option=com_content&task=view&id=7&Itemid=44 [accessed 03.05.2010].

[6] Dudhani S, Inamdar SS, Sinha AK. Assessment of small hydropower potential using remote sensing data for sustainable development in India. Energy Policy 2006;34:3195–205.
[7] Energy Commission of Nigeria (ECN). Renewable Energy Master Plan (REMP). Abuja; 2005.
[8] Dayo FB. Clean energy investment in Nigeria – the domestic concept. International Institute for Sustainable Development (IISD); 2008. Available at http://www.iisd.org/pdf/2008/cei_nigeria.pdf [accessed 07.07.2010].
[9] Nigerian Electricity Regulatory Commission. Handbook for application of license. Available at http://www.reang.org/admin/uploaddocument/ Handbook_on_Procedure_for_Application_for_Licences_amended.pdf [accessed 12.05.2010].
[10] Kaygusuz K, Kaygusuz A. Renewable energy and sustainable development in Turkey. Renewable Energy 2002;25:431–53.
[11] World Bank. Global environment facility. Nigeria: Rural Electrification and Renewable Energy Development; 2005. Available at http://gefeo.org/Documents/Medium-Sized_Project_Proposals/MSP_Proposals/Nigeria_-_Rural_Electrification___Renewable_Energy.pdf [accessed 21.06.2010].
[12] Karekezi S, Kithyoma W. Renewable energy in Africa: prospects and limits. In: The workshop for African energy experts on operationalizing the NEPAD energy initiative. 2003. Available at http://www.un.org/esa/sustdev/sdissues/energy/op/nepadkarekezi.pdf [accessed 21.06.2010].
[13] Federal Republic of Nigeria (FRN). Renewable Electricity Action Program (REAP). Federal Ministry of Power and Steel; 2006.
[14] Navarrete N. Nigeria pushes for renewable energy with World Bank support. Available at http://www.ecoseed.org/en/general-green-news/green-topics/green- policies/incentives/7320-Nigeria-pushes-for-renewable-energy-with-World-Bank-support [accessed 21.06.2010].
[15] National Bureau of Statistics. The Nigerian Statistical Fact Sheets on Economic & Social Development, Federal Republic of Nigeria, 2006.
[16] Kalitsi EAK. Problems and Prospects for Hydropower Development in Africa, The Workshop for African Energy Experts on Operationalizing the NGPAD Energy Initiative. 2003. Available from: http://www.un.org/esa/sustdev/sdissues/energy/op/nepadkalitsi.pdf. [Accessed 07.07.2010].
[17] Energy Commission of Nigeria (ECN). National Energy Policy (NEP), 2003.